Reference Concentration for Shelf Sediment Transport Models

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LONG-TERM GOALS

My long-term goals are to advance understanding of sediment transport processes. In this context, the long-term goal of this project is to advance understanding of the *reference concentration,* i.e. concentration of suspended sediments at a small distance above the seafloor. The scientific interest is in relating this *reference concentration* to the forcing conditions of waves and currents. The new contribution in this effort is to observe the *reference concentration* using a new instrument MSCAT.

OBJECTIVES

My objective within this project is to obtain field data on *reference concentration* and its variability as determined by variations in wave-current forcing conditions. Additionally, I shall characterize the size distribution and suspended velocity distribution of suspended sediments in the field.

APPROACH

Two field experiments are planned to make the measurements of the *reference concentration* under varying forcing conditions. The experiments will be at different sites, one being in waters off Martha's Vineyard, Massachusetts, and the other being in Florida's sandy shallow coastal zone. A suite of laser diffraction sensors will be deployed for measuring the suspended particle size distribution and concentration, settling velocity distribution, and the *reference concentration*. These measurements will be made using, respectively, the LISST-100, LISST-ST and MSCAT systems. The first two of these instrument systems were developed by this PI with ONR-MG funding over the years (Agrawal & Pottsmith, 2000; Agrawal & Traykovski, 2001). These instruments are commercial products of this company now. The MSCAT is a new instrument that is yet to be proven in the field. The instrument suite will be mounted on a tripod and the tripod shall be left on the seafloor for a period of a month or more at a time. The instruments are all battery powered and internally recording. Thus retrieval of the tripod will mean data recovery.

WORK COMPLETED

The principal task of the reporting period has been the development and testing of the MSCAT instrument. This has been a difficult development for the following reasons. The MSCAT instrument is based on the same laser diffraction principles that are embodied in the LISST series instruments. This

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14. ABSTRACT
My long-term goals are to advance understanding of sediment transport processes. In this context, the long-term goal of this project is to advance understanding of the reference concentration, i.e. concentration of suspended sediments at a small distance above the seafloor. The scientific interest is in relating this reference concentration to the forcing conditions of waves and currents. The new contribution in this effort is to observe the reference concentration using a new instrument MSCAT.

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requires the observation of light scattered from a laser beam into small angles, from 0.1 degree to 20 degrees. These are small forward scattering angles which forces the system to be bi-static, i.e. have two housings one of which is a transmitting system and the other is a receiving system. This is OK so long as the size of housings is of no consequence, as for the LISST systems, that are typically used at distances of order 1 meter from the seafloor or more. The MSCAT, however, is required to be used at small distances, of order centimeters from the seafloor, where flow disturbance can cause scour and confuse the measurement unless the sensor itself is small. As a consequence, the sensor dimensions scale with the distance above the seafloor. For this reason, the original MSCAT instrument was of a design shown on the left. The transmitting and receiving optics were enclosed in a common housing, and a pair of prisms folded the optical path. Despite several engineering iterations on this design, we eventually found it impossibly sensitive to misalignment resulting from water pressure on the windows. As a result, we have redesigned the entire instrument. The figure below shows the old and new concept designs. The new concept is similar to the successful LISST designs and is assured of immunity to pressure. As of this writing, the new-design instrument is being fabricated in a machine shop. Preliminary assembly is expected in the first week of October. A field trial is planned before the end of December 2002.

In addition to the focus on MSCAT development, further new developments have been carried out that support the general field of sediment transport studies using LISST sensors. These are:

Size Distribution and Settling velocities measured with LISST-100 and LISST-ST

- A new inversion algorithm has been developed for converting stored multi-angle laser scattering data into particle size distribution; the algorithm achieves greater stability and improves size-resolution;

- New concept optics have reduced background light by orders of magnitude, broadening the dynamic range of turbidity over which size-distribution can be measured;

- The use of new-concept alignment targets permits superior measurements on the largest particles (this is a critical issue as large particles scatter predominantly into small angles, which makes alignment critical);

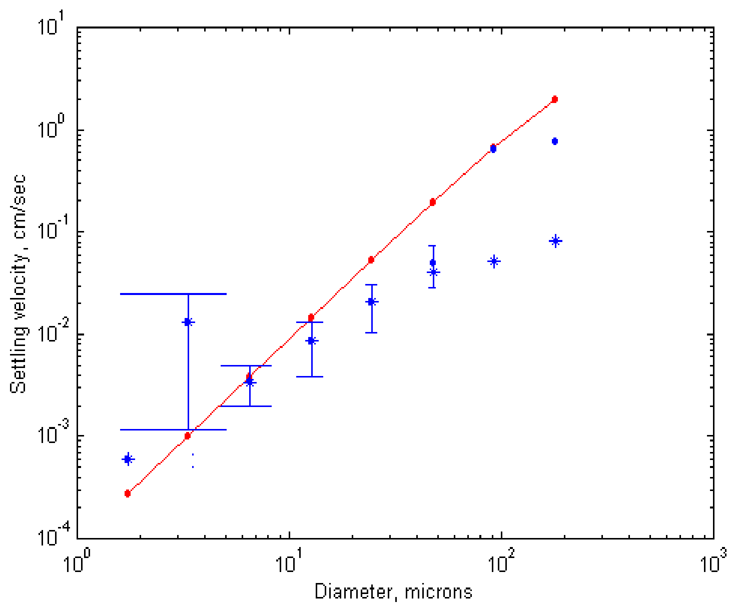
- Better algorithms have been developed for estimating settling velocity spectra; we show settling velocity estimates from data at LEO-15 in the figure above.

- New research, presented at Ocean Sciences meeting 2002, better models scattering from random-shaped natural particles, as opposed to spheres that are the basis of previous light-scattering models. This work continues; it's implications are to improve the accuracy of size distribution estimates by using a scattering kernel matrix that is suited to the natural particle shapes;

- A strategy to prevent bio fouling is now in fabrication; using a mechanized retro-fittable shutter, windows shall be kept out of light and in a biocide environment. This is a critical requirement for all optical sensors in the highly productive waters of Florida.

RESULTS

Among the most striking results of this work is the observation of settling velocity spectra in an associated program of sediment transport research. In this field experiment at the Rutgers University's LEO-15 site, settling velocity spectra were observed over a 45-day period of daily experiments. The settling velocity spectra are shown in the figure below. The relatively straight line is for the well-known Gibb's formula that is believed to describe behavior of unflocculated particles. The progressively smaller settling velocities for increasingly larger particles support the suggestion of a fractal nature of these particles, whose density therefore decreases rapidly as their size increases. This work is now in preparation for publication.



Settling velocity vs size from LEO-15. The red line is for Gibbs' law, blue dots are data. These data are averaged over 20 settling experiments, conducted over a 2 month deployment. The data suggest a fractal nature for the larger particles and will be reduced to a fractal dimension shortly.

A second key finding during this period concerns the light scattering properties of natural, random shaped particles. The relevance of this property is to sizing by laser diffraction because the multi-angle scattering is inverted using this property. In the absence of theoretical or empirical data describing random shape effects, we have used the spherical model. However, laboratory tests with ISO-13201 dusts, separated by size in a tall stratified settling column, reveal significant and intuitively consistent insight. It has been found that the secondary diffraction maxima of spheres, (also more familiar as the side-lobes of a disc transducer acoustic beam) disappear when the particle shape is random. In effect, interpreting multi-angle scattering from random shaped particles as scattering from spheres *invents* fine spheres upon inversion. A quantitative study is underway.

IMPACT/APPLICATIONS

The knowledge of size dynamics in boundary layers, as well as sediment settling velocities is central to all modeling. These data should advance modeling efforts.

TRANSITIONS

The data on size-distribution and settling velocity distribution is now being made available to modelers.

The newly tested MSCAT sensors will be rapidly transitioned to the scientific marketplace so that the study of *reference concentration* can become broadly driven.

RELATED PROJECTS

This PI is also involved in sediment dynamics research in the ONR funded HYCODE project. In that project, temporal behavior of size distributions has been studied in the bottom boundary layer over a month long deployment. Furthermore, the entire water column was studied from a profiling LISST-100. The instruments used in the present work and HYCODE are ONR funded.

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PUBLICATIONS

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